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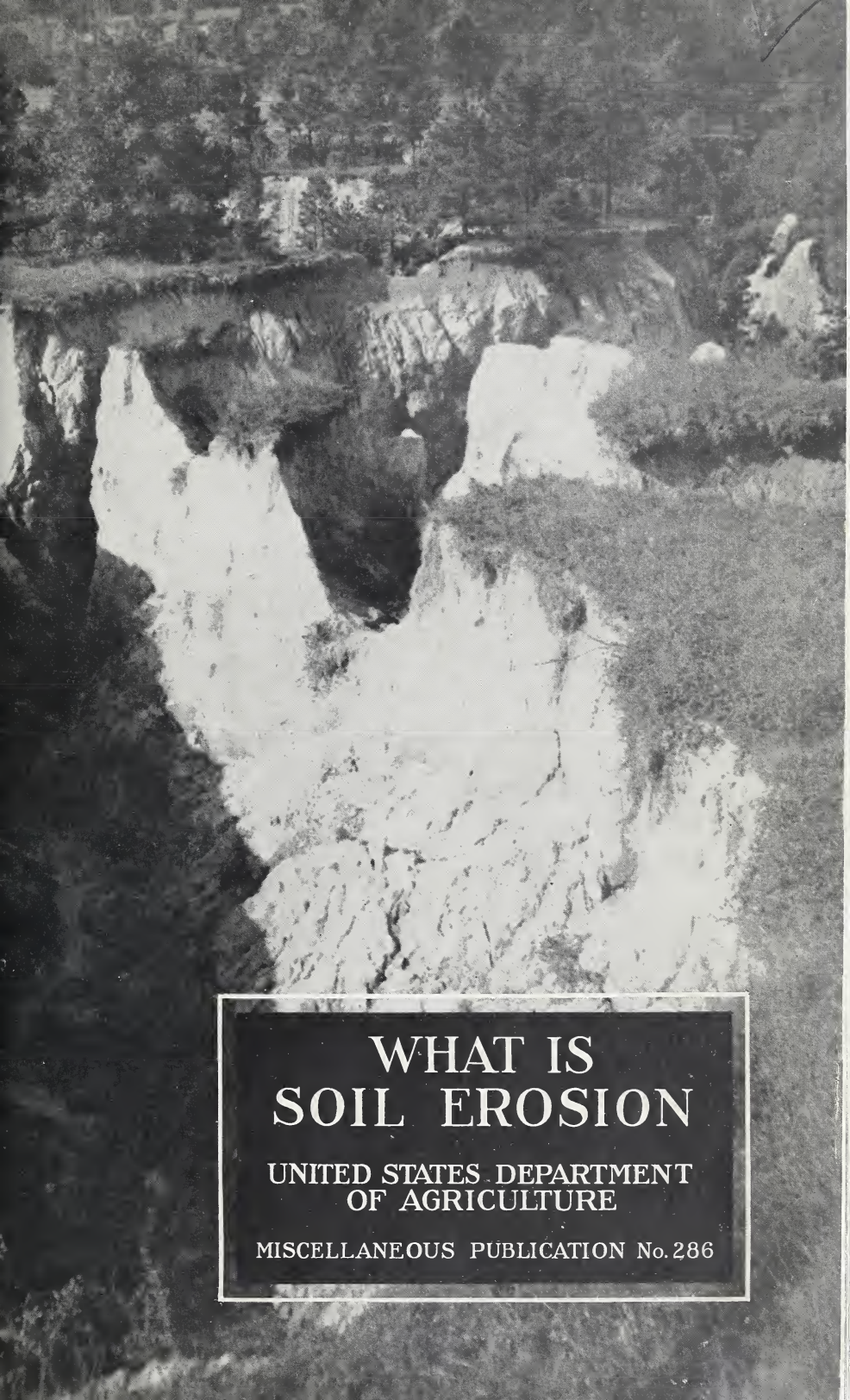

WHAT IS SOIL EROSION

UNITED STATES DEPARTMENT OF AGRICULTURE

MISCELLANEOUS PUBLICATION No. 286

FOREWORD

Erosion is a natural process which has been sculpturing the face of the earth since the first winds began to blow and the first rain to fall; but it has been studied by geologists for little more than a century. As a geological process erosion is a result of the impact of climatic forces such as rainfall, frost, and wind upon the land under varying conditions of slope and cover of natural vegetation. In those areas where climate and soil will support a mantle of vegetation under natural conditions, the geologic norm of erosion, or the normal rate of erosion, has been no faster than soil formation. With the leisure of geologic action, soil-forming processes have made weathered rock material into topsoils and subsoils and have produced the soil resource of agriculture. But when land is cleared of its natural cover of vegetation to prepare it for cultivation, and when soils are bared by overgrazing or by fire, exposure to the direct attack of wind and rain, from which the soil had been protected for thousands of years, induces erosion of an entirely different order. This process is designated "accelerated erosion" or "man-induced erosion" or "soil erosion." Most important, it generally proceeds on sloping land at a rate far in excess of soil formation. This means gradual soil destruction, or suicidal agriculture unless the use of land is changed or appropriate measures for safeguarding the soil resource are put into effect.

Soil erosion and its control constitute a complex problem, requiring for solution the coordinated efforts of specialists in many lines. In this publication soil erosion is discussed by a geologist as an accelerated phase of natural erosion. The study helps materially to clarify our understanding of the erosional processes and aids in our analysis of the problems of erosion control and soil conservation in land use.

W. C. Lowdermilk,
Chief, Soil Conservation Research.

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WHAT IS SOIL EROSION?

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CONTENTS

	Page
Soil erosion—a destroyer of lands	1
Erosion and its work	2
Regional differences in erosion and natural land forms	5
Erosion by rainfall and running water	14
Mass movements of the soil	48
Aspect or directional effect	50
Erosion by wind	72
Erosion—past, present, and future	80

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The great gullies of Stewart County, Georgia, started so slowly that men lived a long lifetime there and paid them no attention; yet now after every hard rain you can hear them grumbling and gnawing at the surrounding farmland; and see them crumbling and fingering their way into the landscape three or four more feet at a time. * * *

—*H. H. Bennett*

Soil Erosion—a Destroyer of Lands

FOR COUNTLESS AGES wind, rain, running water, and other natural forces have been wearing away the land. Great valleys have been carved in the earth's surface, and vast areas have been reduced to level plains. Geologic erosion of this sort is one of the most fundamental natural processes and the results of its action may be seen about us everywhere.

Under natural conditions a partial balance exists. The ground is protected by the vegetative cover. Erosion is retarded, and topsoil develops, very slowly it is true, but faster than normal erosion can carry it away.

As soon as the lands were cleared soil erosion began to take its toll. Washing of the soil was recognized in colonial times but only the most enterprising farmers took sufficient care to protect their lands. New homesteads and good farms were always available in the West and all too many farmers worked their land until it was exhausted and then moved on.

Soil erosion of the violent type seen on our agricultural lands today is not a normal process of nature. Man has upset the natural balance by removing the vegetation. The resulting accelerated erosion of the soil is an abnormal condition which becomes progressively worse and which, unless treated in the proper way, will surely be death to agriculture in the areas affected.

If we are to check this destructive use of the land we must take stock of the situation. Each field must be examined and its troubles analyzed. If the condition is serious the assistance of specialists may be needed—agronomists and soil experts to advise on the care of the land and cropping systems, geologists to help interpret the erosion conditions and aid in planning cures. The cause of the present condition of the lands, the best methods of improving them, and the outlook for the future must all be investigated. Then, having determined what is wrong, a course of treatment must be planned which will arrest the destructive erosion and will bring the lands back to normal condition and productivity as soon as possible. Erosion-resisting or soil-building crops may be needed. It may be necessary to divert water from gullies and construct new systems of terraces and outlet ditches to take care of the run-off. On steeper slopes or

seriously eroded fields a long period of rest or retirement from service and return to woodland under the care of a forester may be dictated.

Signs of soil erosion are visible to everyone, but recognition of the present and future implications is less easy. To learn what is happening to our agricultural lands we must look at erosion critically. We must differentiate between normal and accelerated erosion and must know the significance of each. Continuity of slopes on the land surface, streams well adjusted to the valleys in which they flow, slow uniform downhill creep of the soil mantle, and streams and rivers flowing clear except when in flood are all signs of natural erosion—indications of a perfectly normal condition of the landscape. Quickening of the pace of erosion, due to changes wrought by man, has produced erosion land forms which are definitely abnormal. They are evidence of soil wastage which has already done great damage and which, unless checked, threatens to destroy our agricultural lands and means of livelihood.

Erosion and Its Work

ALTHOUGH THE PROCESS may go on so slowly that it can scarcely be detected, soil erosion is sapping the vitality of farms everywhere, and over periods of time the loss is very great. Gullies are the most spectacular symptoms of this destruction. Starting as small rills, gullies may grow to terrifying size. Some of those in Stewart County, Ga., one of which is shown in the frontispiece, are more than 100 feet deep. Gullies even a few feet in depth interfere with cultivation and make the land less suitable for pasture. Unless prompt action is taken to check growing gullies they get out of hand. Fields, farms, or whole townships may have to be abandoned.

Less obvious but no less important is sheet erosion. This form of soil erosion is particularly detrimental because it attacks the topsoil first. Removal of a cubic yard of soil each week from an acre of land would scarcely be noticed, but if continued for 30 years, or one generation, the loss would amount to more than 11 inches from the entire surface. In many parts of the country only this upper soil horizon is suitable for cultivation and when it has been lost farming can scarcely provide subsistence. Wind erosion also attacks the soil surface and in the wind-swept portions of the Great Plains the particles carried by dust storms consist almost entirely of topsoil.

Soil erosion is simply a special type of the general erosion which has sculptured the lands. Ever since the world was young, rains have washed soil and rock down the hillsides, winds have blown up clouds of dust or sand from dry areas, and loose surface soil and rock waste

have moved slowly down slopes toward the sea. Erosion has carved great canyons and broad river valleys. Mountains have been worn away by the continual wash of running water. Material removed from the lands and carried by swollen rivers has filled lakes, formed broad flats along low-lying river channels, and built great deltas into the sea. Geologists have read the story of the rocks and have found that the land surface today is very different from what it was thousands or millions of years ago. It is constantly changing.

The major elevations and depressions of the earth's surface are due to the rocks of the earth's crust. Solid rock is beneath us everywhere. It may outcrop at the surface as in rugged mountain areas unsuitable for agriculture. It may be covered by a layer of soil a few inches to many feet in thickness, or it may be concealed by a great body of water. None the less the land surface is underlain everywhere at no great distance by solid rock or bedrock.

Portions of the earth's surface have in times past been slowly uplifted from the sea and other portions gradually submerged. Parts of the continents have been pushed up to form great mountain chains and plateaus, others have been depressed to form broad valleys. Volcanoes have poured out molten lava onto the lands. These processes are still going on today and earthquakes give evidence of the unrest of the earth's crust. The changes take place slowly, and it is only by careful observation that geologists have been able to learn much about their action. It is these major movements of the earth that build the great land masses. They are the constructional processes of the landscape.

Just as climate is important in determining the natural vegetation and type of soil of any region, so climatic elements determine in large part the rate and character of natural erosion. The decay and disintegration or *weathering* of rocks is controlled by the action of frost, heating and cooling, wetting and drying, and other conditions dependent on weather and climate. Soil and broken rock formed by weathering are eroded and carried away by the action of running water from rain and melting snow, by wind, or by the downhill creeping and sliding movement of masses of soil and rock by the general process of mass movement. In these ways the great constructional land forms are gradually worn down. Plateaus and mountains become so dissected by streams that their appearance is entirely changed. Erosion of soil and rock produces the *destructional land forms* of the earth's surface. Valleys carved by streams, rock surfaces scoured and polished by wind-blown sand, cliffs cut by waves, valleys deepened by moving glaciers, channels carved by underground water, and depressions or scars left by landslides are a few of the common erosional land forms.

During the wearing down of the land surface, materials being carried away may temporarily be dropped on their way to the sea. Deltas

are built into lakes and rivers at points where streams drop most of their load of sediment. *Sand dunes* are formed where winds deposit material they have transported. *Moraines* are developed from rock and soil carried by glaciers. *Sand bars, spits,* and *beaches* are constructed by wave action. *Hummocky deposits* are formed from material moved by landslides. These and many other land forms are produced by temporary deposition during the destructional process.

The land forms mentioned above are developed in the natural course of events. They are physiographic forms produced by ordinary geologic processes. Geologic erosion wears away both soil and rock slowly and more or less steadily unless man speeds up the process and starts new types of erosive activity by his use of the lands. Where, under natural conditions, there is a good vegetative cover, the action takes place so gradually that new soil can form as fast as the old is washed away. When the vegetation is removed and the soil is exposed to the weather, erosion is greatly accelerated and soil formation cannot keep pace. Sheet erosion becomes more active and gullying supplements the normal stream erosion of a healthy landscape.

Consideration of the large land forms produced by geologic erosion through countless ages helps us to interpret the smaller land forms produced by the ever-so-much-faster erosion of the bare soil. These duplicate in a small way the larger features of the landscape which have long been studied by geologists. In erosion land forms the geologist finds concrete evidence of the way erosion processes work. By analyzing the forms produced, he can learn facts about the manner and rate of erosion which are difficult to determine while the processes are actively in operation.

The following pages illustrate and describe the effects of erosion on the landscape. They point out from the geologic standpoint the significance of the many erosion land forms. With a clearer understanding of these forms we shall be better able to recognize the processes in their incipient stages and so avoid the hazards which they foretell.

Regional Differences in Erosion and Natural Land Forms

A COMPARISON of natural landscapes of humid regions with those of arid lands reveals certain characteristic differences.

Humid areas tend to have smoothly rounded topography. The landscape is made up of sweeping curves from hilltop to valley bottom. Flat plains or vertical cliffs are rare. Rainfall aids in the formation of soil by hastening the decay or weathering of the rocks. In many parts of the Southeastern States, where temperatures are high and rainfall abundant, solid rock is overlain by 25 to 50 feet or more of soft material which looks like rock but which is badly disintegrated and can easily be dug into with a shovel or pick. This is neither rock nor soil but represents an intermediate stage in the soil-forming process and is spoken of as the *parent material* of the soil. The soil itself is seldom more than 3 to 6 feet thick. Of this the topsoil, or loose upper layer a few inches to a foot or 18 inches thick, is in most areas much the easiest to work and the most productive. Under natural conditions the soil in humid and subhumid lands is well covered by vegetation, either forest or grassland depending on soil conditions, altitude, and other facts. Erosion progresses slowly because little soil or rock is exposed to the elements.

Arid lands tend toward sharp angular topography. The graceful curves characteristic of humid lands are rare; horizontal and vertical lines are prominent. Stream channels have flat bottoms and steep walls. Flat-topped hills are bordered by vertical cliffs. Due to inadequate rainfall vegetation is poor and thin. Soil is usually rather shallow and bedrock outcrops frequently at the surface.

These differences in the land forms of humid and arid regions are due in large part to differences in the degree of protection offered by vegetation. Removal of the vegetative cover in humid lands exposes the soil, and erosional forms similar to those of sparsely vegetated arid lands usually result. In this way local *badlands* and areas of angular land forms are produced in humid regions. Gullies, once started, erode so rapidly and maintain such steep walls that vegetation cannot gain a foothold. Lowering of the ground-water level adjoining the gullies reduces the suitability of the area for plant growth and erosion spreads still further. Removal of vegetation thus tends to begin a progressive change toward a landscape more characteristic of arid climates.

THE FOREST-CLOTHED HILLS along the Kentucky River, in Lee County, Ky., shown above, and the rolling grassy plains of southern Wisconsin, below, are typical of the natural landscape of humid and subhumid regions where rainfall is adequate. Slopes are gracefully curved except in rare places where rock outcrops project through the soil cover. Valley walls slope evenly. Hilltops are well rounded. Sharp angles and straight lines are unusual.

THE NATURAL LANDSCAPE of arid or semiarid regions tends to be angular. The flat floor and vertical banks of the *arroyo*, and the cliffs and flat-topped upland of the area of McKinney County in New Mexico, shown above, are typical of regions deficient in precipitation. Owing to the character of the rocks and erosion processes in large areas of the Southwest broad flat-topped *mesas* or smaller *buttes* such as the one below are common land forms.

THESE DIFFERENCES between the characteristic landscapes of arid and humid regions are due in large part to the protection offered by vegetation. In humid climates where a luxuriant forest or grassland normally covers the surface, soil erosion can have little effect. Much of the rainfall is absorbed, and vegetation binds the soil and protects it against the action of running water or wind.

Plowing up the natural sod and cutting or burning down the forests exposes the soil to the destructive processes. This field in North Dakota and the recently cut-over hillside in Virginia will suffer from soil erosion unless proper care is taken.

SOIL ACIDITY caused by fumes from beehive coke ovens has killed the vegetation on the Pennsylvania hillside shown above. This condition is also common around ore smelters in many other States. Thinning of the grass cover by heavy overgrazing of cattle has exposed the soil of the Wisconsin pasture below.

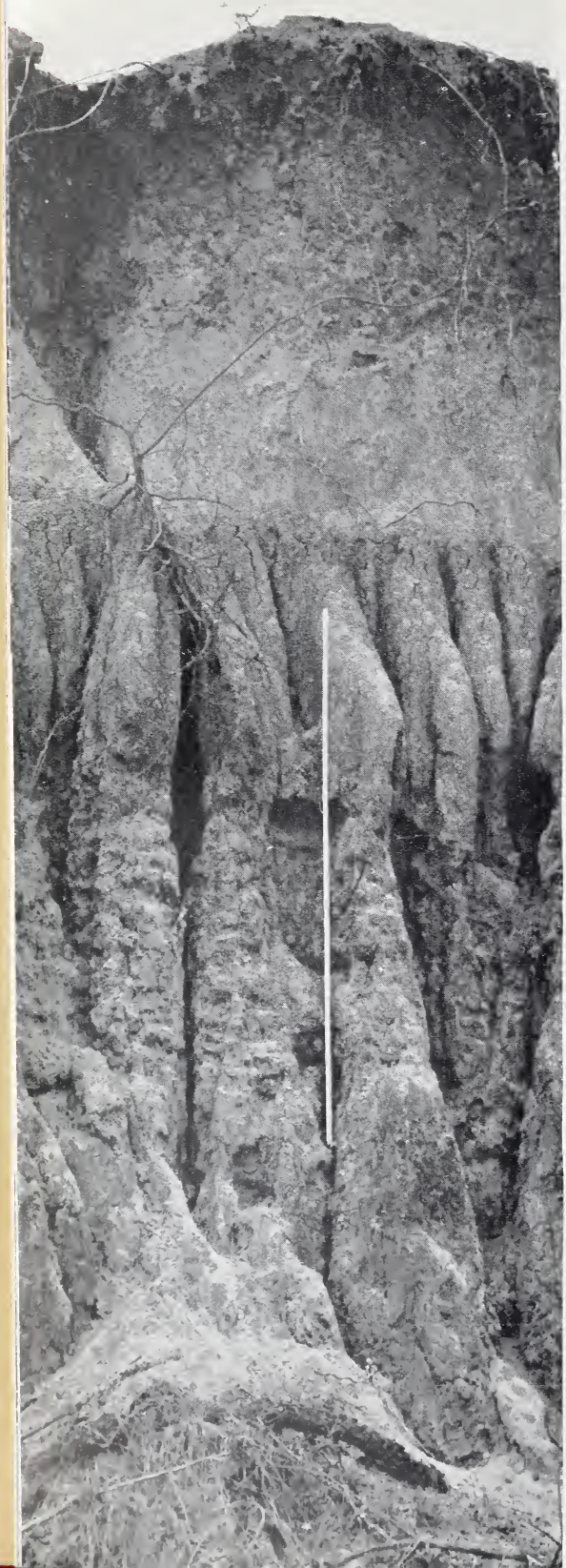
By removing the natural vegetation in humid regions and thus destroying the protection of the soil, man exposes the land to erosion much as it is exposed under arid climates. There the vegetative cover is naturally sparse and the soil and rock are an easy prey to the erosive processes.

SOUTH DAKOTA'S Big Badlands show types of land forms produced by the action of rain and running water under a semiarid climate. These badlands lie along the break between the high plain in the background and a broad flat in which the White River flows. The area consists of weak sandstones and shales lying in almost horizontal layers or beds. These are soft rocks formed by the consolidation of sand and mud. They are easily worn away. Sand and clay eroded from the badlands are transported by small wet-weather rills and streams and are poured into White River. More and more of the high-plain area is being carried away in this fashion as these great natural gullies eat their way headward. A few outlying remnants of the flat upland still stand but in time they too will be worn away.

This and other areas of badlands in the Western States, because of their fantastic forms and delicate coloring, are visited each year by thousands of tourists. These lands are of scenic value only.

THIS FARM LAND in Monroe County, W. Va., shows real badland topography developed by accelerated erosion in a humid region having an annual rainfall of 35 to 50 inches. The hillside in the background is in the early stages of destruction. The sod cover has been broken. Sheet wash and rilling have removed the fertile topsoil, and gullies are now developing. In the flatter area at the base of the hill sod-capped remnants of the old surface are still present but are steadily being undermined by gullying. The subsoil and parent material exposed within the gully are of low fertility. Slopes of the walls are so steep that vegetation would have difficulty gaining a foothold. Erosion is progressing so rapidly that few plants can maintain themselves on the gully floor. Soil and rock washed from this area have covered fields lower on the slope to a depth of 3 to 4 feet.

Unless precautionary measures are taken, hillsides like this one may develop into big badlands of the East.



THE PICTURE SHOWS part of a wall 17 feet high in a railroad cut in Franklin County, Miss. The roots at the top lie in rich silt loam topsoil several inches thick, developed on loess, a fine silty deposit which covers great areas in many States in the Mississippi Valley. Franklin County is on the eastern edge of the loess region where the deposit is very thin. The bottom of the loess subsoil can be seen about 6 feet from the surface. Below 6 feet the materials are entirely unsuitable for cultivation. First is a sun-cracked layer about a foot thick which contains much clay. From the top of the white ruler on down are alternate layers of clay and coarse sand very similar to the rocks of the Big Badlands of South Dakota and weathering into the same fluted forms.

THE LUXURIOUS GROWTH of vegetation on the loess soil in the background is in sharp contrast to the semiarid appearance of the miniature badland where the loess has been removed. This view was taken in Mississippi one-half mile from the picture on the opposite page and in an area that receives an average of 58 inches annual rainfall.

The badlands seen below on the Navajo Indian Reservation in New Mexico show extremely close spacing of steep rills. The flat top of this erosion remnant is still capped with about 1 foot of soil.

Erosion by Rainfall and Running Water

WHERE HEAVY RAIN falls on thick sod or on the plant litter of a forest floor the force of the fall is broken by the vegetative cover. Part of the water is absorbed by the vegetation, part evaporates, and part soaks into the ground where it is available for future use by plants. There is little or no surface run-off, and washing or erosion of the soil is almost negligible.

Rain falling on clean-cultivated fields or on bare spots in hillside pastures stirs up the unprotected soil. During heavy showers thin sheets of water muddied by suspended earthy material flow across these bare surfaces. On gentle slopes clay and silt transported by this *sheet wash* tend to seal the pores of the soil and form a waterproof crust. Little water soaks into the ground. Objects which shed the rain protect the soil on which they lie. The surrounding unprotected soil is loosened by the driving rain and carried away, leaving miniature soil pillars several inches high capped by pebbles, leaves, lichens, roots, or corn shucks. These serve as a key to the amount of recent erosion by sheet wash. Such erosion is shown too by plant roots which stand above the present soil level and by the exposure of layers of the soil profile which are ordinarily concealed beneath the topsoil. This is particularly striking in appearance where the topsoil is gray or buff colored and the subsoil is red as in parts of the Southeastern States. A loose crumby or fluffy layer on the surface of clayey soils is another sign that the sheet erosion processes are active.

True sheet wash follows no definite channels. Water tends to concentrate its flow, however, and small drainageways soon develop. A single shower may be enough to cause rills several inches deep, but not too large to be obliterated by normal cultivation. Unless the area is soon protected by vegetation or the rills destroyed by cultivation, the channels will continue to grow with each successive rain. The deeper rills may increase in size and form gullies too large to be smoothed over by normal methods of tillage. Special labor must then be expended in filling them or in the construction of dams.

The large volume of material which can be removed from a field by sheet wash and rilling is also shown by the amount of sand and silt accumulated at the lower end of sloping fields after a hard rain. Although plants high on the slope may be left with their roots uncovered, others, where the soil is deposited, are often completely buried.

GULLIES MAY DEVELOP from rills, ruts in old roads, depressed cattle trails or paths, drainage ditches, improperly constructed terrace outlets, or other lines along which running water is concentrated. Periodic flow of water removes from the floor the material washed or fallen into the gully and gradually deepens the channel. Caving and slumping of the gully walls increase the width, and flow of water from tributaries helps develop side channels which eat into adjoining areas.

Starting with a small channel or "shoestring gully" across which a man can step, a gully may increase in size until it is large enough to hide a cow, a house, or a whole village. The depth to which gullies can cut is determined in large part by geologic conditions, particularly the thickness of soil or depth to bedrock, the character and resistance of bedrock, the gradient of the gully floor, and the amount of material transported by the stream in the gully. Gullies in some areas can cut downward only a few feet before encountering firm, resistant rock. This is the case in much of New England and in many mountainous areas. Where the soil is thicker or the bedrock deeply weathered, there may be no resistant material within 50 or more feet of the surface. Such conditions are found in the deep loess deposits in some of the Mississippi Valley States, and in parts of the Piedmont area of Virginia, North Carolina, South Carolina, Georgia, and Alabama where solid rock rarely is present at or near the ground surface. Under such circumstances gullies can grow rapidly to tremendous size.

In other parts of the Piedmont, layers, veins, and dikes containing resistant minerals occur in the bedrock and form local barriers against the deepening of gullies. As a gully channel is cut downward, the stream may encounter a resistant barrier of this sort which will act as a dam and form a waterfall or rapid in the gully channel. Falls and rapids in creeks and rivers are usually due to the same cause. Any barrier of this sort forms a local *base level* which determines the gradient of the channel upstream and the depth to which it can be cut. Check dams are sometimes constructed in gullies to serve the same purpose and thus control the depth of channel erosion. The water level in a lake or river also acts as a base level below which its tributary streams cannot erode.

If the flow of water through a gully is large and the debris load small, the water can cut into the floor and pick up additional material. If the water is heavily loaded with solid matter, it may actually deposit and raise the level of the gully floor. Deposition is encouraged by vegetation, dams, or other obstructions which help check the velocity of the water.

STREAMS AND RIVERS have always been active agents of erosion but have become still more violent owing to changes which man has brought about. Removal of natural vegetation has increased the proportion of the water which runs off during or immediately after a rain. This increase in flow has transformed streams which formerly flowed gently in shallow channels into raging torrents which cut deep gorges and attack the lands bordering their courses.

Streams in mountainous or hilly areas ordinarily flow at a high gradient in narrow steep-sided valleys. They are vigorous and actively erode the bottoms of their channels. In less rugged areas where the lands have been worn down through the ages the streams and rivers flow in flat-bottomed valleys with broad flood plains. Here cutting is largely sideward and the streams swing or meander from one side of the valley to the other, broadening the flood plain and eroding away the banks. Undercutting by streams causes caving and slumping from the banks, and lands adjoining the stream are gradually eroded away. Cutting out of brush or other vegetation along the banks of a stream increases the danger of lateral erosion by removing this protection from the stream's banks.

PART OF THE RAINFALL enters the ground and percolates downward through pores in the soil and crevices in the rocks. It carries downward the finer soil particles and dissolves soluble materials such as limestone. In some areas saturation by ground water so softens the rotten rock or parent material of the soil that it actually flows although lying some feet beneath the surface. Movement of this sort accelerates the caving of gully walls. Water entering the ground through cracks which open parallel to a gully margin and through holes made by burrowing animals or decayed plant roots sometimes causes the collapse of large blocks of the gully wall.

THE TYPE OF SOIL EROSION in any region and the differences in erosion at different seasons of the year depend in part on the character of the rainfall. Intense rains give a larger proportion of immediate surface run-off than do slow drizzles. Although the intense rains usually last but a short time and cover only small areas, it is these rains that cause the greatest amount of sheet erosion and gully-

ing. It is these "gully washers" that enlarge rills to form gullies, and that periodically deepen and clear out the channels, washing downstream the material fallen from the gully sides. Terrace breaks and failures of inadequate check dams or baffles are usually caused by rains of this type. Intense rains are most common on warm summer and fall afternoons and are often, though not always, accompanied by thunder and lightning. Some of the torrential rains in the Southeastern States result from hurricanes which sweep northward from the tropics.

The slow drizzling rains, or " 'tater soakers", may be so light that they cause little or no surface run-off. These prolonged rains saturate the soil and are of great benefit to crops, as they replenish the supply of water in the ground. By lubricating the soil, however, they cause caving and slumping of the sides of streams and gullies; they promote soil creep and the slippage of large soil masses on hillsides. These gentle but prolonged rains usually cover a wide area. They are somewhat more common in winter than in summer. Although the rain comes slowly and runs off the land in leisurely fashion, the total amount of water may be very great, and it is these rains which cause our major floods.

THE DISTINCTION between rills and gullies is purely one of size. Rills can be filled or obliterated by normal cultivation. Gullies are too large to be cured in this way and require special measures for their control.

RAIN FALLING IN A FOREST has the force of the fall broken by the leaves of the trees. In this hardwood forest in Virginia there is little underbrush, but dead leaves form a thick covering over the ground. Rain dripping from the trees falls on the vegetable litter and is absorbed. In normal rains there would be little or no surface run-off from this forest. Thanks to the abundant vegetal mold the soil is open and porous. Water enters the ground easily and is stored for use in periods of drought. Even in the heaviest downpours, water flows over the surface slowly. It is clear because it carries little or no sediment. Under natural forest conditions soil is not only held in place but is also slowly but constantly enriched by the decaying vegetation.

THIS OKLAHOMA WOOD LOT shows a markedly different condition. The amount of vegetal litter is small because of heavy overgrazing and the animals have kept the underbrush cropped or trampled down. Lack of humus protection has allowed not only the topsoil but several feet of subsoil to wash away leaving the roots of the trees exposed. Run-off is rapid; water has little opportunity to soak into the ground because there is no longer an absorbent cover of leaf litter. The loose-textured topsoil has been completely removed and the subsoil which is now exposed absorbs water slowly and washes away easily. Streams of water flowing from this wood lot are brown with sand and silt from the soil. Water runs off the surface rapidly and little is stored in the soil for the use of the trees during drought periods.

RAIN FALLING ON A TIGHT SOD COVER is absorbed rapidly and very little is lost as surface run-off. On the left side of the fence in this New Mexico pasture there is a good grass cover due to wise range management. The pasture at the right has been overgrazed by sheep. Growth is sparse and the type of vegetation is inferior. Many bare spots are visible.

Everything favors the land at the left. More water is retained owing to slower run-off; therefore better growth of grass is made possible. There is little chance for water to concentrate in channels and cut rills or gullies. There are no bare spots where wind can blow the soil away. Under the present management the land on the left will continue to improve while that at the right will become steadily less productive and less valuable.

THIS HOG LOT and its surroundings in southeastern Minnesota show extreme differences in erosion due to different land use. Trampling and rooting in the area at the left have completely denuded the soil. Sheet erosion and rilling have carried away the more productive upper layer and a gully is now dissecting the land still further. During dry periods wind erosion takes its toll. Grass and weeds provide good protection for the soil to the right of the fence.

Where there is an abrupt change in land use and erosion along a property line, cooperation between farmers is needed to check the destruction. Unless preventive measures are taken on the barren land shown above, the gully and rills will eat headward into the higher plot at the right. Under other circumstances water concentrated on one property may cause gullying in adjoining lands farther downhill. Study of the work of running water and the development of gullies shows that neighborly cooperation over a wide area is essential for the success of soil-conserving measures.

TRUE SHEET WASH occurs where a thin layer of water flows across the ground carrying with it some of the surface soil. Most of the land surface is not smooth but has many minor irregularities which tend to concentrate the water into small channels or rills.

Cultivated land often suffers heavily from sheet wash. This spinach field in New Jersey has only a 3-percent slope, yet water washing across the field has moved much of the sandy loam topsoil and buried some of the plants. Rills are beginning to develop but are of very shallow depth.

Even on this gentle slope the advantage of horizontal cultivation is seen. If the rows in this field had been run up and down the slope, rill development would have been more severe and a much larger proportion of the soil would have been washed away to lower lands.

THE STONINESS OF THE SOILS in New England, New York, and many Northern States is due in part to the tremendous load of rock debris dropped there by the ice sheets or glaciers which covered that area during the great ice age. Sheet erosion accentuated the condition and is partly to blame for the stoniness of this run-down pasture in Steuben County, N. Y. Gradual washing away of the fine materials down the 25-percent slope of the land has left an *erosion pavement* or residue of rock fragments at the surface of the ground.

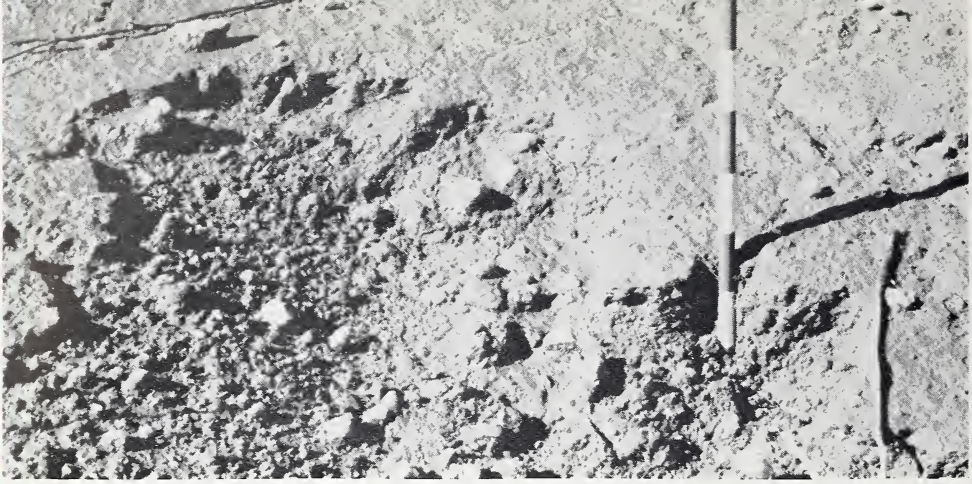
The shallow gully developing on the upper part of the slope at the right may soon reduce the productivity of this pasture still further. Thin vegetation covers the channel at present but is not strong enough to assure protection in a hard rain. Mullein, which is abundant on this hillside, indicates the impoverished condition of the soil.

RAPID SHEET EROSION due to human use of an area often results in marked wearing down of the land. In this way a single field, or a whole farm or ranch, may be eroded to a level several feet below its surroundings.

The top picture gives evidence of severe sheet erosion on a farm near Spartanburg, S. C. A scarp almost 1½ feet high divides the cottonfield at the left from the strip of residual sod along the road. Field study shows that beneath the sod the soil has been protected and there is still a layer of topsoil, or A horizon, several inches thick. Although the cottonfield is contour tilled and contains old terraces the topsoil has been removed and erosion has cut far down into the B horizon, or subsoil. Much of the damage may have been done generations ago before the land was terraced. Recent washing has occurred when terraces broke and were not immediately repaired. In some of the shoestring gullies leading to former terrace breaks only a few inches of subsoil are left over the parent-rock material. In the foreground is seen one wall of a gully 20 feet deep, tributaries of which are gradually eating back into the field.

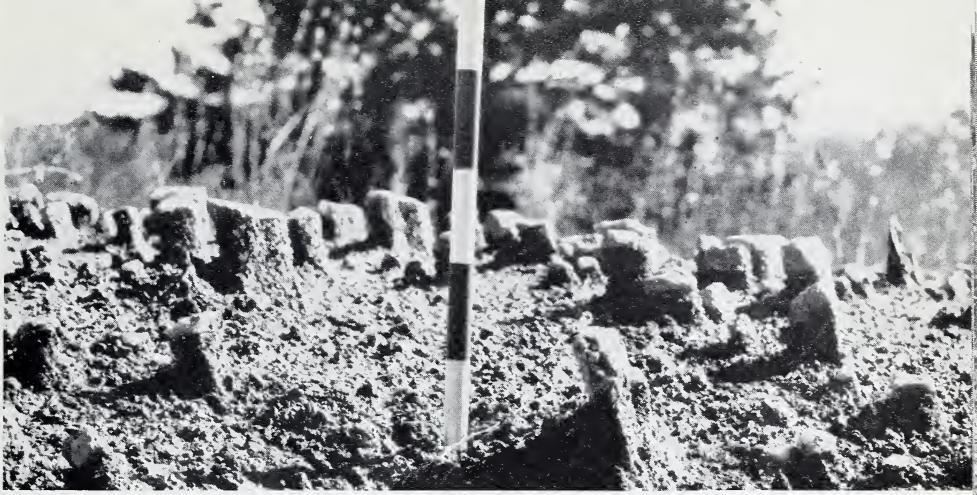
In the middle view, near Dalhart, Tex., differences in land use have led to a lowering of several feet in the ground level on the far side of the line fence due to another form of erosion. The land at the right was plowed in 1909. The following year was exceptionally dry and the farming venture failed. Wind erosion carried away the soil. On the left side grazing has been heavy but there is still sufficient cover of short grass and sagebrush to prevent violent wind scour.

The picture at the bottom shows a property-line fence in Barren County, Ky. The farmer owning the land at the left has practiced soil-conserving measures and has retained most of the original soil. Sheet wash and rilling have removed 2½ feet of soil from the land at the right.



THE SMOOTH SURFACE seen beyond the vertical rod, which is marked in inches, indicates that rain and sheet wash have had a puddling effect on this clayey soil. A film of clay covers the soil surface and effectively seals the pores so that rain water flows off with little chance to be absorbed. In the foreground where the crust is broken the soil is actively washing away.

Soil-conservation geologists studying the erosion processes have found that in denuded areas miniature land forms such as those shown on these pages give good indication of the processes at work and the amount of material removed. Each little pillar in the picture below, for example, is capped by a layer of lichen which sheds rain and protects the soil of the pillar against erosion. Some of these pillars are almost 4 inches high and show the recent removal of that thickness of soil from the surrounding area.



EVEN MORE COMMON are miniature stone-capped pillars. Those above are on idle land in an old pasture in Spartanburg County, S. C. The painted rod stands vertically and the tilt of the pillars indicates that driving rain coming from the left was important in shaping them. Similar pillars are sometimes capped by leaves, corn shucks, roots, or anything that will shed the rain.

Large land forms of the same sort, but formed by normal geologic erosion, are common in areas where weak rocks contain more resistant masses or where boulders of hard rock have come to rest on easily eroded materials. The large sandstone erosion pillars, or *hoodoos*, seen below are in Monument Park, El Paso County, Colo.

THE EXPOSED ROOTS of this ash sapling struggling to maintain itself on the edge of an eroded field in South Carolina indicate a loss of 1 to 3 feet of soil by sheet erosion and shallow gullying during its short lifetime.

In winter the top layer of clayey soils is loosened by the growth of spew frost, or needle ice, just below the surface. The view below shows earth and pebbles which have been raised 3 inches by frost action of this sort. It has been observed during study of sheet erosion that when the ice crystals melt, the soil they carry comes to rest several inches farther down the slope. The total amount of soil moved in this way during one winter is large, and the cumulative effect over a number of years can make considerable difference in the appearance of a sloping bank or hillside. Frost action further speeds soil removal because the loosened soil can easily be washed away by rain and melting snow.

THE ACTION of needle ice in winter and of other processes such as pitting by the beat of rain, alternate heating and cooling and wetting and drying, at all seasons produce on bare surfaces of loamy clay soils a fluffy or crumby layer which we may call a *crumb mulch.* On sloping surfaces of bare soil this loose mulch may be as much as 3 inches thick. It absorbs light rains and helps to retain moisture in the ground but is not especially hospitable to vegetation.

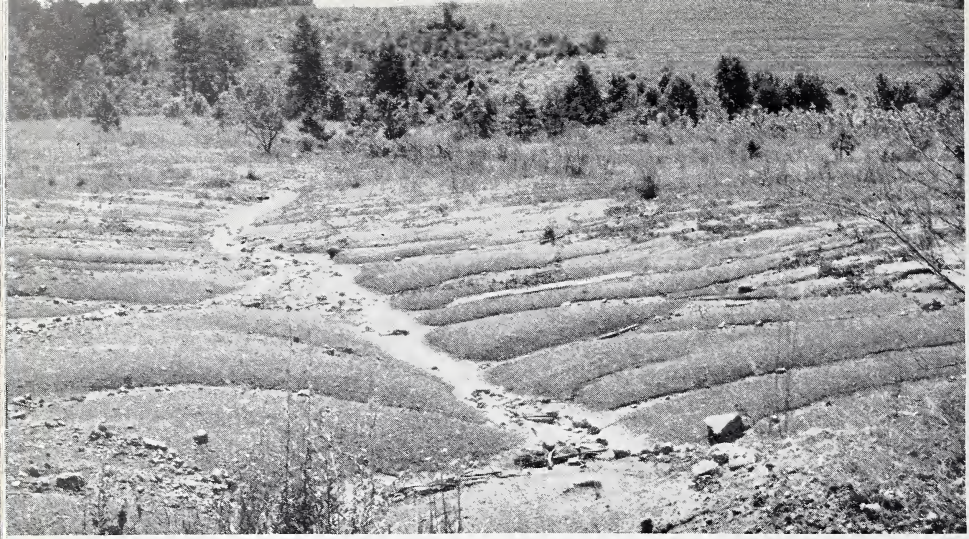
On the walls of the South Carolina gullies shown on this page the crumb mulch is about 2 inches thick. It has been washed away from the channels and, in the lower view, is washing off the slope as well. Tests show that even in summer additional layers of this loose mulch will form quickly when the existing layer is washed away.

WHERE SHEET WASH CONCENTRATES in furrows or minor channels the scouring action of the water is accentuated and rills tend to form. Prominent rills may develop in one season or even in a single rain. This area in Washington, near Palouse, shows the effects of a rain estimated at 1.5 inches in a period of 30 to 40 minutes. The land had been plowed for summer fallow and tilled once. Run-off was so intense that in the rills in the background at the right the soil was removed down to the plow sole. Note that the minor rills are roughly parallel to the direction of cultivation. Even on this gentle slope contour tillage would have helped to prevent sheet wash from developing into rilling.

Part of the eroded material was deposited in the major channel in the left foreground.

THIS IS PART of the Black Belt of Alabama, once famed for its rich black soil and fine cotton. Now it is a scene of desolation. Lack of crop rotation and disregard of the need for erosion control have brought the land to its present almost incurable condition. Because of the open cultivation, fields used for continuous cotton are particularly subject to erosion.

In the background in this view some of the soil remains and there is a moderately good stand of grass and trees. In the foreground, however, sheet wash and rilling have carried away both topsoil and subsoil. The bedrock or parent material which is left is a platy chalk formation which cannot support even a growth of weeds.

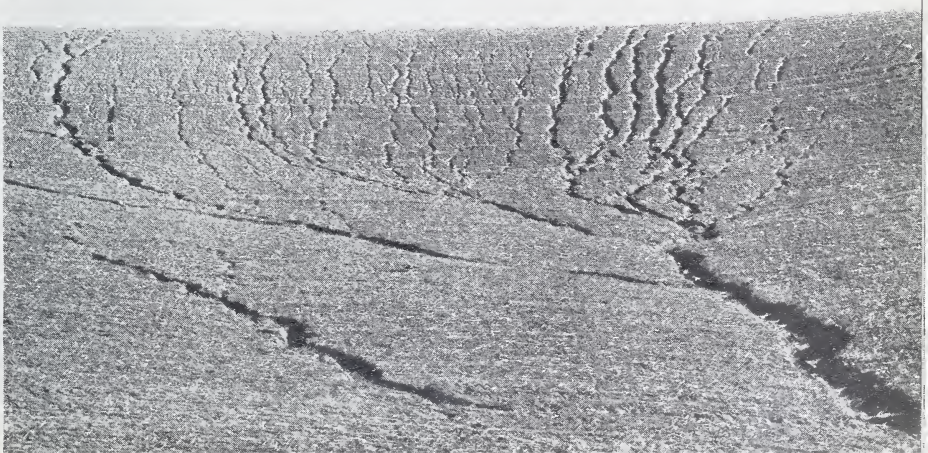


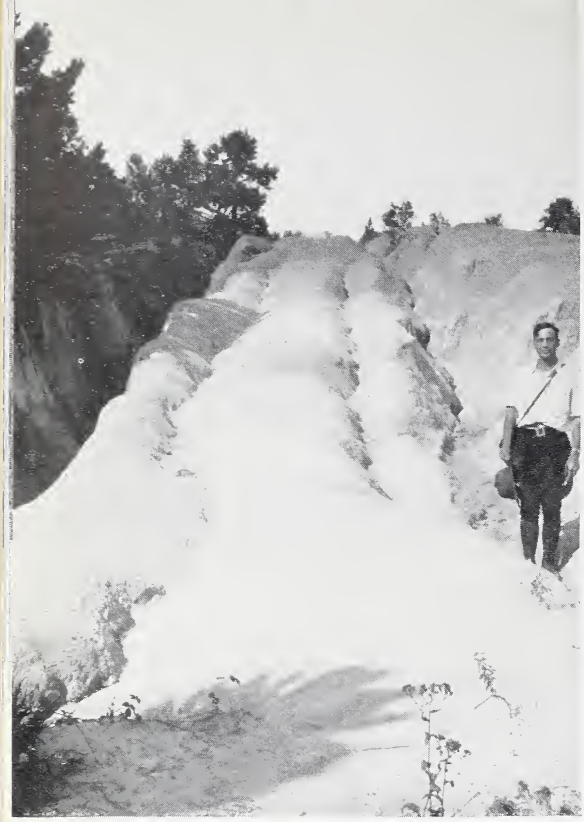
THE SOUTH CAROLINA PASTURE SHOWN ABOVE lost much of its topsoil through sheet erosion. Rilling and gullying have since cut down into the subsoil. Years ago this was a terraced field cultivated on the contour. The grassy bank in the foreground is the remnant of an old terrace which has broken over. Water from the terrace break carved the central gully and enlargement of old furrows produced the tributaries on both sides.

Below is a similar area in California. The subsoil in both of these areas is much less fertile than the topsoil and when the plant cover and A horizon have been removed little or no vegetation takes hold to protect the subsoil, or B horizon, from erosion.

UNLESS PREVENTIVE MEASURES ARE TAKEN rills enlarge into shoestring gullies. The size to which these will grow depends on many factors. The gullies pictured above are on a hillside in western Pennsylvania. They are about 3 feet deep but are not likely to enlarge rapidly. Because of loose rock in the soil and outcrops of bedrock at several places in the bottom of these gullies down cutting will be slow but the channels may broaden and remove more and more of the surrounding soil. Even if gully erosion never cuts deeply into this hillside, serious damage will result because the removal of the shallow soil leaves only unproductive bedrock.

The network of shoestring gullies on this hillside of Whitman County, Wash., is typical of the rapidly eroding Palouse silt loam of that section.



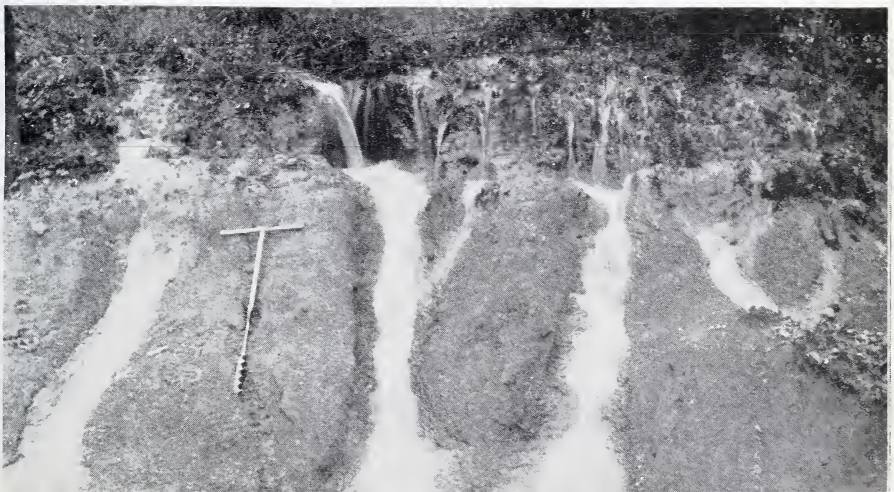


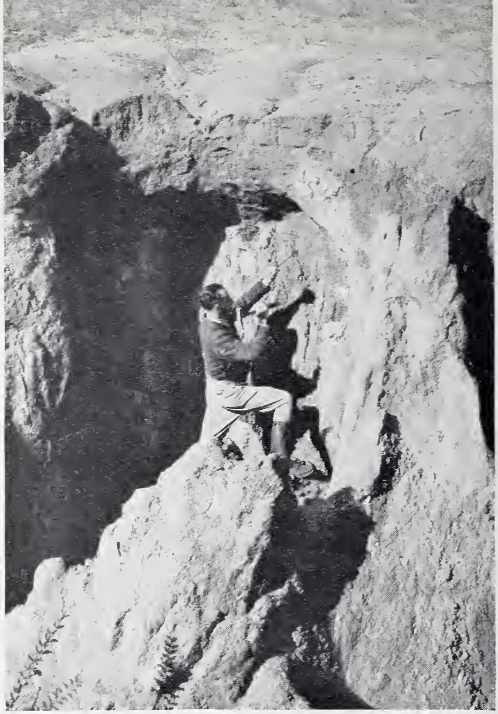
GULLIES ENLARGE by various processes depending on the character of the soil and rock, slope of the land, cause of the gully, and the rainfall and run-off of the area. Water flowing through the channel gradually deepens the gully and removes material which has fallen from the walls or has been washed in by tributaries. The ditches and ruts of this old road in South Carolina have all developed into gullies by washing.

THE GULLIES SHOWN BELOW, in Cooke County, Tex., follow the lines of old cattle trails and were scoured almost entirely by running water. They are relatively shallow and V-shaped in cross section.

EROSION AT WORK is illustrated in these two pictures taken by geologists studying gully erosion during a heavy summer rain near Spartanburg, S. C. Water surging down the gully shown above has carved a series of *pot holes*. Rocks and sand in the holes serve as tools with which the churning water abrades the sides and bottoms of the cavities steadily making them larger.

BELOW, WATER FROM A BREAK in an old terrace is cutting away the soil. Rills are being formed which, unless properly cared for, will soon grow to gullies.





GULLIES DOWN STEEP SLOPES on weak material are usually deeper toward the head. A gully tends to cut into the hill until the channel reaches a very gentle gradient at which water will just flow. Thus the gully floor may emerge level with the land surface low on the hillside but head in an abrupt wall many feet high, constantly becoming higher as it cuts back into the hill. Water enters the head of the gully as a cascade down the walls or as a waterfall plunging to the gully floor. Headward cutting and caving at the lip of the waterfall lengthens the gully.

A *plunge pool* 15 feet deep where water enters the head of a gully in Love County, Okla., is shown above at the left. Note the caving of the walls above the white ruler 6 feet long. The sod forms a lip from which the water plunges to the gully floor.

At the right is a plunge pool in the head of a gully near Spartanburg, S. C. Here the topsoil has been eroded away from the gully rim and the water plunges over a projecting lip of tough clay subsoil. The geologist is driving rods into the gully wall to serve as markers for the study of the rate of erosion in this type of soil.

THIS LARGE GULLY is of a type common in the Piedmont area of South Carolina and adjoining States. The man is standing in the water furrow of an old terrace, drainage from which has formed a plunge pool about 12 feet deep. The topsoil is gone from the area around this gully. The rim is formed of tough clay of the subsoil, or B horizon. Water flowing over the lip and into the plunge pool slowly cuts away the clay at the gully rim. Whether the flow is large or small, however, a part of the water clings to the wall and flows back underneath into the cave.

The parent material of several of the most widespread soil types in the Piedmont is a granitic rock which, owing to the warm humid climate, is deeply weathered and crumbles readily when touched. The thin film of water which trickles back along the roof and walls of the cave soaks this rotten rock and so softens it that large masses of the wall slide or fall away. The lower part of the cave is gradually enlarged in this manner and the roof drops off in large blocks as its support is removed.

THIS DEEP PLUNGE POOL receives the water from a roadside ditch. The back trickling of water down the wall in the gully head has formed a large cave which extends under the drainage ditch and threatens the road itself. Water which falls from the lip of the plunge pool strikes the gully floor with considerable force and washes out the caved material accumulated in the channel. Both pictures on this page are from a gully near Spartanburg, S. C.

A VERY DIFFERENT TYPE of plunge pool is shown below. Here the forest root mat overhangs the soil and forms a ragged lip from which the water falls. Back-trickling and caving have caused rapid enlargement of this gully head.

THE GULLY AT THE RIGHT is 50 feet deep and is eating its way headward destroying the plains in Caddo County, Okla. It is particularly dangerous because it is growing along the course of an old rock gorge which was filled with sand and silt thousands of years ago, but which is now being exposed. Geologists have found that old gorges of this type underlie large areas in this part of the State. Any gully that happens to uncover a buried gorge may grow to tremendous size.

LARGE GULLIES ARE FOUND in almost all parts of the country as, for example, the one shown below in Pike County, Ill. Imagine the problem of healing these great gashes in the landscape to stem the erosion and protect the surrounding lands.

THESE PICTURES SHOW how gullies sometimes grow headward by seepage of water through tension cracks. The gully head is cutting along the water furrow of an old terrace that was not provided with proper outlet protection.

In the left-hand view, taken in the summer of 1936, water is disappearing through the tension crack to which the geologist is pointing. Only in very heavy rains does water flow over the lip and plunge to the gully floor. A jet of water may be seen coming from the roof of the cave. Some of this water falls to the floor and washes out accumulated soil. A more important effect is produced by a part which flows downward in a thin film adhering to the roof and walls. This is similar to the back-trickle of typical plunge pools. It softens the material in the lower part of the walls and growth of the cave results.

This cave enlarged slowly but steadily from June 1936 to January 1937. Early in January, following a long period of rain, the arch on the cave gave way as shown at the right. The wall as far back as the tension crack collapsed, revealing the full width of the seep cave.

This type of seepage and caving is common in gullies cut in heavy subsoils in the Piedmont area of South Carolina.

A GULLY MAY APPEAR to have changed very little over a long period of time. Trees may have grown on its walls and in the channel. Cutting may be so slow that the area may seem to have returned to a natural rate of erosion. The gully may appear to be completely stabilized. This must not be assumed to be a permanent condition, however. A change in land use, drainage area, or vegetation, cutting through of a barrier in the channel, or a change in the height of a major stream or other base level may cause violent cutting and the gully suddenly may grow to many times its former size.

The picture above, taken at Muddy Gap, Carbon County, Wyo., shows the enlargement of a channel by the headward cutting of a fall, or *knickpoint*. Above the fall the stream is narrow and can easily be crossed by a man on foot. Below this step in the stream profile the valley is 18 feet wide with vertical caving walls 7 feet high.

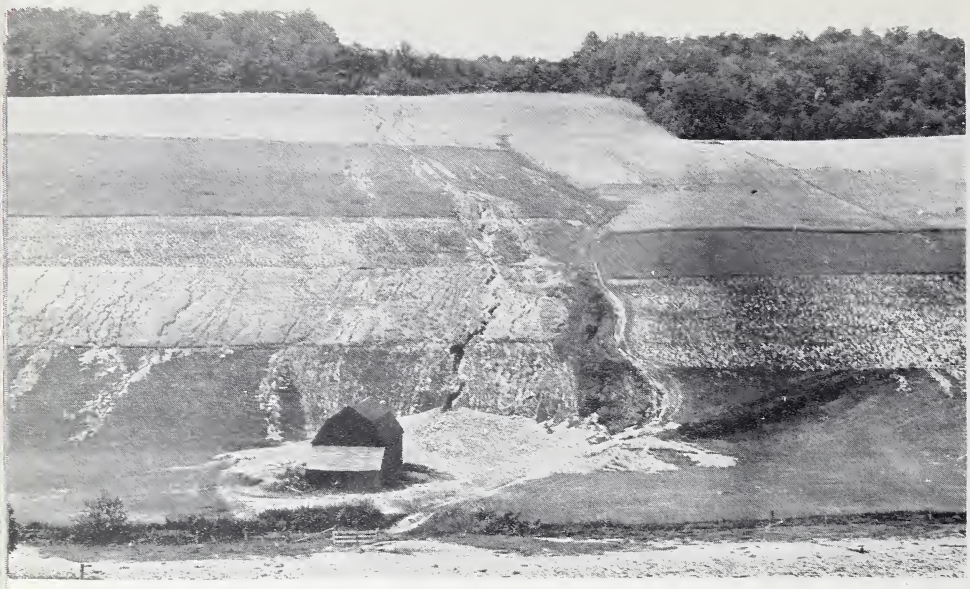
Many supposedly stable gullies later become rejuvenated and undergo a second cycle of cutting. The waterfall here marks the boundary between the small valley formed in the first cycle of cutting and the large valley below being carved in the second.

UNDER NATURAL CONDITIONS the range land in Cassia County, Idaho, shown above could support a good growth of bunchgrass. The area has been seriously overgrazed, however, and now little cover is left. The resulting accelerated run-off has cut a large gully in the valley floor.

The development of a valley within a valley as shown in these two pictures is recognized by the geologist as a clear sign of an increased rate of erosion. The scene from Columbia County, Wash., below, shows old valley slopes meeting at the base forming a broad V. In the bottom of the old valley a narrow gully 15 feet deep has formed. Almost 6 feet of the gully depth was cut in a single winter.

THIS STREAM VALLEY in northeastern Oregon was formerly narrow and bordered by trees, as in the wooded stretch in the background. A few years ago the valley was "brushed out" and has since grown much wider and deeper. This dangerous practice of *brushing out* increases channel erosion and, by rushing the water along, increases the height of floods farther downstream.

Brush was cleared 36 years ago from the banks of the stream in South Carolina, shown below. The stream bed eroded rapidly and by undercutting, the stream produced high scarps on the valley sides; gullies emptying into the stream became steeper and deepened rapidly. This land was once cultivated but is now unsuitable even for pasture.



THIS HILLSIDE IN WESTERN NEW YORK, cut by many small gullies formed during heavy rains in July 1935, shows how material eroded from the lands may be deposited quite close by. Earth removed by rills and gullies on the light-colored strip, planted in buckwheat, was deposited on the meadow farther down the slope. The large gully in the middle drains cleared land beyond the timber and has built a fan of sand and gravel behind the barn.

In the bottom of the South Carolina gully 30 feet deep, pictured below, water has undercut the weak, rotten granite in the wall. Caving and slumping of the material periodically has dammed the gully channel. The flat-topped remnants in the center of the view show levels to which deposited material has filled the channel within the gully before being cut away and removed.

INCREASE IN THE RATE OF RUN-OFF of rain water due to man's use of the land has resulted in greater floods and increased deposition of sediment on bottom lands. Soil removed by sheet erosion and gully cutting is carried down valley by the heavily loaded streams and dropped wherever the current is slack. Much sand and silt is piled onto fertile soils of river flood plains as shown in this valley in Washington County, Ohio. Thin layers of silt are sometimes of benefit, but thick deposits of sand ruin the agricultural value of the land.

The farmer on the property near Mankato, Kans., seen below, has already started clearing the sand and silt out of his house. He can dig out his farm machinery but the deposited material destroys his crops and is an irreparable loss to the lands from which it came.

WATER SOMETIMES FINDS ITS WAY into gullies through underground channels. On this farm in Walla Walla County, Wash., drainage from the drill rows emptied into a squirrel hole and seeped into the gully. Flow of water through the ground enlarged the passage. Caving of the roof of the tunnel eventually will make this an open gully.

Erosion in regions underlain by soluble limestone bedrock develops a group of distinctive land forms known to the geologist as *karst* topography. Water produces solution channels on the surface of the limestone and enlarges joint cracks and other zones of weakness within the rock as shown by the gaping hole in the rock outcrop in northern Kentucky, seen below. Surface streams are rare in regions of soluble limestone because a large proportion of the run-off is carried away through underground channels.

OPENINGS THROUGH WHICH THE WATER PASSES downward into limestone bedrock are known as *sinkholes*. At first these may be small. They may have a cover of soil and vegetation or may show a rim of bare rock. The one from Jefferson County, Ky., seen above, is a typical example and contains a small clump of trees.

Where the drain of a large sinkhole becomes stopped up the depression may accumulate silt, producing a *basin* with a broad flat floor. The basin pictured below in Larue County, Ky., shows old plow furrows. Owing to the restricted outlet, the basin is sometimes flooded to a depth of 3 feet, making the crop yield uncertain.

It is important to recognize these signs of limestone lands because such areas require the use of special methods for conservation of the soil.

Mass Movements of the Soil

THE SOIL on sloping lands is constantly moving downward, sometimes imperceptibly, sometimes suddenly and violently in great landslides or flows. Relatively little attention has been paid to these movements although evidence of this action can be seen in hilly land everywhere. The direct connection between mass movement and ground moisture makes it important that we understand these processes before we irrigate or otherwise increase the soil moisture on sloping lands. Geologists have found that on hillsides the extra weight and improved lubrication furnished by heavy rains has often been enough to start the soil or rock debris slipping down the slope. Movements of this sort damage both the area from which the material is lost and that where it is deposited. Topsoil, removed from one part of the hillside and mixed with clayey subsoil and rotten rock, not only loses its own value but destroys that of the soil on which it comes to rest farther down the hill.

Slumping, or downward sliding in which the moving blocks tend to tilt back toward the bank, is an important process in valley widening. Many curves which look like old meanders are in reality due to slumping of portions of the stream bank. Seepage of ground water from the base of the bank aids this movement. Undercutting by flowing water removes the support from the banks of streams, rivers, and gullies, and allows portions of their walls to slump away. Man has directly and indirectly caused much slumping. Many of the hillside excavations which he makes for foundations, roads, and railroads, or to obtain gravel or other road-building materials, induce movements of the soil mantle farther up the slope. Indirectly, many works of man bring about accelerated stream flow, a common cause of undercutting.

In a large area in Ohio, West Virginia, and Pennsylvania, where the land is hilly and the soil is formed from shale, saturation of the ground by heavy rains causes soil movements which sometimes affect an acre or more of the surface. Cracks develop on moderately sloping hillsides and blocks of ground slump downward, tilting back toward the hill. Immediately downhill from the cracked area the surface is little disturbed but farther down the slope a bulge appears. Earth has flowed downhill beneath the vegetation and accumulated lower on the slope raising the sod or woodland surface into a protruding dome which in some cases cracks open allowing mud and water to escape. Slumps and *earth flows* of this sort cause great loss to farmers,

and involve heavy expenditures for the maintenance of highways and railroads. Fields where slips of this sort have occurred are difficult to cultivate, and once slipping has started, recurrent movements may continue over a long period.

Caving along stream banks, gully walls, or other undercut slopes is another form of mass movement which plays an important part in destroying agricultural land and increasing the area of gullies and stream channels. As in the case of slumping, undercutting by flowing water, or by the work of man, and the removal of support by the softening or crumbling of the underlying materials leaves stream banks, or other steep walls, in an unstable condition, and caving is a common result.

The type of mass movement active in any area varies according to climatic conditions, character of the rocks, and the slope of the land surface. In semiarid regions where the topography is rugged and overgrazing or cultivation has left the ground poorly protected by vegetation, heavy rains sometimes start large saturated masses of mud, sand, and boulders flowing down slope, usually in a gorge or stream channel. *Mudflows* of this sort are common in several of the Western States. Many have poured forth from the canyons along the front of the Wasatch Mountains north of Salt Lake City, Utah. Flows there have built large fans of debris covering valuable farm lands, highways, and railroads. At some localities they have damaged or destroyed farm buildings and schools. Improved regulation of grazing and the planting of all denuded areas on slopes which drain into steep canyons help to prevent the occurrence of mudflows.

The most widely distributed but least spectacular form of mass movement is *soil creep*. It is active on sloping lands everywhere. Movement is fastest at the surface, where the action of frost heaving and changes in temperature and moisture are at a maximum. It is effective to a depth of several feet and carries much soil downhill to the streams each year. Evidence of this slow creep may be seen in the tilt of trees and fence posts and in many other ways. It is an important process in producing the rounded topography of humid regions. Streams and rivers carve the great valleys of the earth's surface and carry the eroded soil and rock on down to the sea. The shaping of the rolling hillsides between the rivers, however, can be due only partially to running water in the form of sheet wash and rills. Soil creep is a vital part of the process and must have played an even larger role before man upset the natural balance by depleting the native vegetation. The effects of soil creep are best seen in regions such as the Southeastern States where the rocks are deeply weathered, but where the residual soils remained undisturbed for long ages prior to the coming of man.

Aspect or Directional Effect

ON ANY HILLSIDE the activity of mass movement and erosion by running water depends in part on *aspect*, the direction in which the slope faces. Aspect affects the amount of sunshine received and also the drifting of snow by prevailing winds. North-facing slopes get much less warmth from the sun than do south-facing slopes. For this reason snow stays longer on north-facing slopes and the ground is protected against erosion. Temperature changes are also less marked on north-facing slopes and rock weathering and creep proceed more slowly. Winds tend to carry snow across the crest of a hill and let it accumulate in drifts on the protected side, usually the east or southeast. The deeper accumulation of snow on the lee side of a hill may help to protect that side from erosion during the winter months, but snow accumulation is not beneficial everywhere. The midday sun often melts the edges of the snowbanks and in some soil types constant saturation by this water causes slips which, unless cared for, may be the beginning of extensive hillside erosion. Because of these local differences in climatic effectiveness the different sides of a single hill may be adapted to entirely different uses. Soil-erosion problems, too, may vary widely within a small area, the differences being caused solely by the exposure or aspect of the particular field or slope.

THIS HILLSIDE IN WESTERN NEW YORK is steepest at the base where it has been undercut by a small stream. Early in July 1935, 8 inches of rain fell within 2 days, so saturating the soil that in several places it broke loose and slipped down, leaving bare scars. The slides occurred on a slope of about 60 percent which seems to have been just steep enough to cause movement. Parts of the slope were not affected and it will be noticed that slippage reached only to the top of the steep area and did not involve the more gentle land above. Steep slopes need the protection of a good vegetative cover but, as this picture shows, even a good sod will not always prevent erosion when other conditions are especially favorable. Slides of soil or debris are common forms of mass movement and constantly threaten land on steep slopes.

THE PICTURES AT THE RIGHT show three stages in the slumping of the bank of a stream near Spartanburg, S. C. Slump is one of the most characteristic types of mass movement of the soil and is very important where streams undercut their banks. Where the toe of a bank is cut away an unstable condition is produced. Material at the foot of the bank tends to move forward and surface cracks parallel to the stream develop on the upland a few feet back from the rim. The ground breaks up into blocks which sink or slide downward, but in doing so tend to tilt back into the slope or cliff from which they broke away.

On October 14, 1936, when the first picture was taken both ends of the slump block were still attached to the bank. The center of it had sagged downward some 6 inches.

On October 16 and 17 exceptionally heavy rains, totaling 5 inches, raised the level of the stream and increased seepage of ground water from the bank. By the morning of the 17th, as shown in the second picture, the block had broken free at the right end and had moved downward 10 inches, tilting back toward the bank. The size of the block can be judged from the white ruler 6 feet long lying on the ground.

Little movement occurred for some time following, but winter rains in December again set the block in motion. By January 8, 1937, when the third picture was taken, it had broken free from the bank and had moved down leaving a *slump scarp* more than 4 feet high. The block was then beginning to break to pieces. Further stream erosion at the base of the bank and additional softening of the material by water seeping from the coarse sand and gravel underlying the soil will soon remove the remainder of this slump block.

The next time the stream is in flood undercutting will be renewed and new cracks are likely to develop. The widening of the stream course at the expense of the meadow will thus continue. Slumping is an important factor also in the widening of gullies.

MASS MOVEMENT MAY BE CAUSED directly by the work of man and once started may continue to destroy valuable land.

This slump near Bath, N. Y., shows complex movement in which there are several slip surfaces and many blocks instead of one. A cut was made in the hillside almost 4 years ago to obtain material for a road fill. Slumping resulted and has now eaten its way 50 feet into the field above, breaking the land and making it unfit for agriculture. If additional earth and gravel are excavated from the base, slumping is sure to continue. Even if no more material is taken away the break will move back some distance and, depending on the slope of the land, may migrate hundreds of feet up the hill and destroy the fields and woodlands.

The smoothly rounded hills in the background are typical of humid climates where soil creep acting beneath the vegetative cover plays an important part in evening out the minor irregularities in the landscape.

EXCAVATION FOR THE SPILLWAY of a dam in Clark County, Kans., brought down this large segment of the adjoining hillside. The man standing at the base of the exposed slip surface at the right gives an idea of the size. The slump block slid downward some 20 feet and tilted back toward the hill.

Undercutting at the base of slopes upsets the natural equilibrium. Slump movements of this type are common. Road and railroad cuts through deep soils often start movements which cause real trouble for the engineer.

The hills in the distance at the right show an irregular scarred or hummocky surface pattern which suggests to the geologist that similar slip movements have occurred there in times past.

On the slope at the right just beyond the slump are small hillside steps usually called cattle terraces or sheep paths. In many areas these, too, are formed by slumping on a much smaller scale, as is shown on page 60.

THE LAST FEW PAGES HAVE ILLUSTRATED slumping caused by natural and artificial undercutting and have shown the land forms produced by that type of mass movement. Slumping may also result from flowage of the soil, or earth flow, lower on the slope.

Earth flows are very common in eastern Ohio, West Virginia, and southwestern Pennsylvania where the land is hilly and the bedrock is mostly a slippery shale.

The example shown above occurred in a rotation pasture field in Guernsey County, Ohio, and was of combined earth-flow and slump type. Heavy rains early in August 1935 saturated the ground and prepared the way for the movement. As the picture shows, the earth beneath the surface actually flowed and forced the sod cover up into a large turf roll. Downhill flowage produced tension in the soil farther up the hill. The surface cracked and typical slumping took place.

The break at the top occurred on a 30-percent slope and flowage at the toe came to a stop on a 20-percent grade.

PROTRACTED RAINS IN JANUARY 1937 washed large amounts of soil from fields throughout the Ohio Valley and caused floods of record height. These same rains saturated the soils and brought them to a semifluid condition so that many earth flows occurred during January and February.

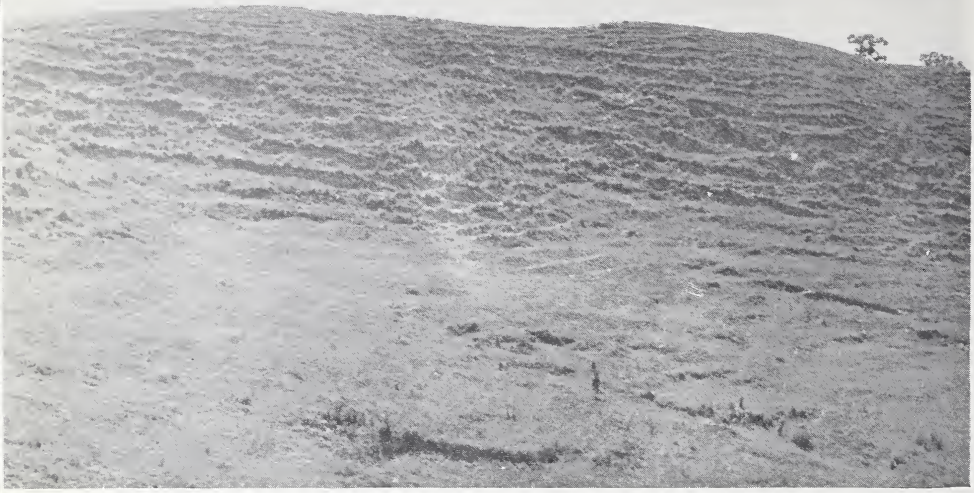
One of these flows in Tuscarawas County, Ohio, is shown here and on the two pages following. In the picture below are seen the typical bare slump scarps at the head of the movement and, in the foreground lower on the slope, a toe, or turf roll, several feet high. Most of this toe has a relatively smooth sod cover and resembles the bulging lobe farthest down the hill in the picture on the opposite page. In the lobe nearer the middle of that picture doming from underneath was more pronounced and the material appears to have been less fluid. The sod there has been broken and pushed up in rough blocky fashion.

THIS CLOSE VIEW SHOWS the bulging turf roll at the toe of the Tuscarawas County earth flow illustrated on the preceding page. Soil flowing downhill beneath the sod raised the ground surface here about 3 feet and strained the turf until it broke apart slightly. In some earth flows, liquid mud runs out between the cracks in the sod. Among the trees on the hillside in the background at the right are irregular scallops which resemble old scarps produced by earth flow and slumping. Certain hillsides in that part of the country are covered from top to bottom by traces of old flows and slumps. To the geologist trained to see and interpret these symptoms such slopes give every sign of instability. Making of cuts for roads or other purposes is very likely to cause renewed flowage and slipping. Paved highways in regions subject to soil slips or earth flows show traces of many old movements where sections of the road have sagged or slid downhill and the pavement has been mended or relaid. Soil-conserving practices must be adjusted to the peculiar geologic conditions in such unstable areas because concentration of water by terracing would increase ground moisture and promote earth flowage and slumping.

THE HEAD OF THE SAME AREA of movement looks like this. The ground has broken into blocks which have moved downward and forward. Individual blocks have tilted back toward the hill as is characteristic of slumping.

If the hillside is left in this condition, surface water will enter the ground through the cracks between blocks and further slippage is likely to result. The farmer can help to avoid future trouble by cultivating this land to smooth out the irregularities and then planting it again to grass.

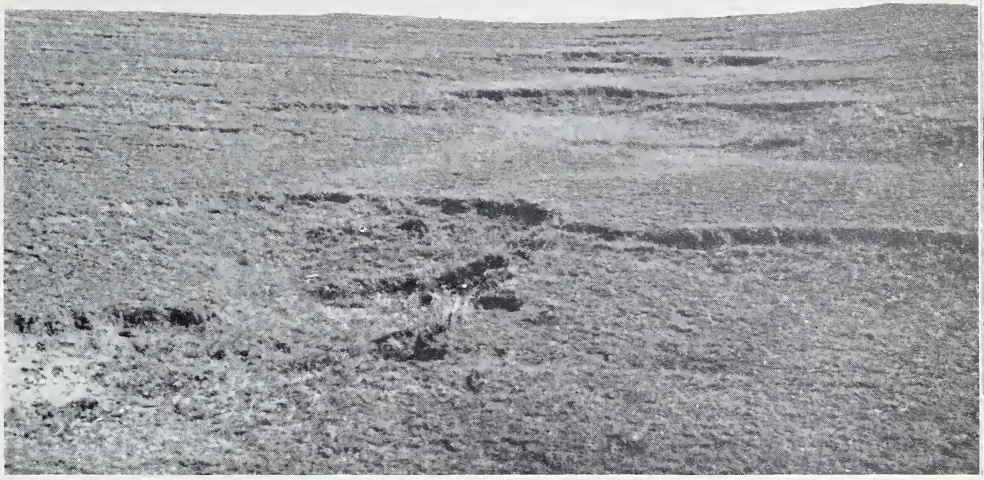
Although earth flow is particularly common and is of great importance in Ohio, West Virginia, and Pennsylvania, it is by no means limited to these States. Earth flows occur in all parts of the country and in many areas the most characteristic land forms are due to movements of this sort. Many flows have taken place in the clay terraces of the upper Hudson River Valley in New York State and in the region around Portland, Maine. Somewhat slower and larger earth flows have affected whole hillsides as in the Gros Ventre River Valley in western Wyoming where an area of several square miles is badly broken and has been moving intermittently since 1909.



THE SO-CALLED "CATTLE TERRACES", "sheep paths", or "cat steps" are common features on hillsides in all parts of the country. They are most frequently seen in pastures and therefore have been generally attributed to the walking of cattle and sheep.

Study of these miniature terraces, better called terracettes, shows that, although some of them are merely trails used by grazing animals, many are due to actual slippage of blocks of the hillside and are a form of mass movement of the soil. Grassy slopes, as in pastures, are more favorable for their development than are cultivated fields or wooded lands. The trampling of animals undoubtedly assists but is not essential to their formation. Terracettes are particularly well developed in areas of loess (p. 12), one characteristic of which is that it tends to cleave vertically and will stand for a long time in vertical walls many feet high. This tendency also makes it particularly subject to slippage along more or less vertical planes.

The area shown above is in western Iowa, where the loess is very thick. Steep hillsides in that section are covered by a series of terracettes, generally several feet high. The arrangement of these little terraces on the hill slopes, the height of individual steps, and the association of these forms with typical crescentic slump scarps indicates the origin of these features by mass movement of slump type.



RANGE LANDS IN THE GREAT PLAINS and also in more humid parts of the country are often scarred by series of low breaks commonly attributed to sheet wash and overgrazing. Those shown above are on a 7-percent slope in Chouteau County, Mont., and are locally called *stepped crescents*.

If we compare these features with terracettes and scarps of larger size typical of slumping, we find marked similarity in surface pattern. Geologists who have studied the stepped crescents on the plains of Kansas have found good evidence that in many cases they are caused by mass movement of the ground. Just as in the earth flows and slumps illustrated on preceding pages, they are formed by vertical sinking of the surface at the upper end of the area close to the crescentic scarp accompanied by downhill flowage of the earth beneath the sod cover.

In Kansas these depressions sometimes develop into long valleys or arroyos a foot or several feet deep and bordered by low vertical scarps. It may thus be seen that land forms which appear at first glance to be carved by running water or wind actually may be due to other causes. Mass movement is acting on the lands everywhere and is a much more important process than we realize.

ONE OF THE MOST IMPORTANT means of widening of gullies and stream channels is the caving of masses of earth or rock from the walls. In this type of mass movement the blocks fall downward and outward without the backward rotation characteristic of slumping.

In the close view above, tension cracks have developed parallel to the wall of a deep gully in South Carolina. The mass at the right is about ready to fall and the other two segments may go within a few days or weeks. More than 1,000 cubic yards of earth have already caved and slumped from the wall of this gully and the action will continue unless drastic measures are taken. Tension cracks of this sort develop where a high gully wall stands unsupported by banks of fallen material. The earth around the rim tends to lean toward the gully and in this way internal strains are set up. Wetting and drying of the soil causes slight changes in volume which accentuate the strained condition. When the accumulated tension is great enough the block breaks from the more stable ground behind.

Cracks may widen gradually or remain for a long period without perceptible movement. Rain, earth vibrations from blasting or heavy vehicles, trampling of cattle, undercutting by flowing water, or any of a number of factors may cause the actual caving of the mass.

WHEN THE BLOCK OR MASS BREAKS AWAY from the wall it falls forward or straight downward, and usually breaks up or crumbles when it lands. The wall of this arroyo in New Mexico shows typical caving where a high bank of earthy material is being undercut by a stream.

Caving of the banks takes place along watercourses of all sizes from small rills to great rivers. Streams which are well established and have reduced their courses to a gentle gradient tend to swing sideways in a series of large, more or less regular arcs or meanders. On the outside of each bend the water cuts into the bank. Earth and rock cave or slump (p. 53) into the river and are carried away. The meanders cut into the valley walls and gradually migrate downstream producing a broad flat-floored valley such as is seen in the lower Missouri and Mississippi Rivers and in innumerable other smaller streams.

Mass movement by caving is thus a vital part of the erosion carried on by streams and gullies although the material may be removed so rapidly that little trace of the caving action is left.

IN SEMIARID LANDS the mudflow is one of the most characteristic and most destructive forms of mass movement.

This aerial photograph shows the steep face of the Wasatch Mountains at Centerville, a few miles north of Salt Lake City, Utah. The flats at the base of the mountains are fine, fertile land used for nurseries and truck gardens. They are part of the floor of an old freshwater lake which once occupied this basin. A former shore line of the lake is seen about one-third of the way up the mountains and is marked by the boundary between grassed slopes below and larger vegetation above.

In recent years heavy grazing on the mountains has depleted the vegetal cover and has accelerated run-off. During severe rains in 1923 and again several times in 1930 wash coming from some of the canyons did serious damage. Rains of July 1930 washed down so much soil and loose rock in Parrish Canyon, shown in the center of the view, that the stream emerged at the canyon mouth as a mass of flowing mud. This mudflow was so thick, or viscous, that boulders and blocks estimated to weigh as much as 200 tons were carried along in the pasty mass. The whitish fan-shaped patch below the mouth of the canyon is the area covered by mudflow debris.

As shown in the aerial photograph, the flow crossed a minor road, blocked the highway to Ogden, Utah, with a layer of mud and rock several feet thick, and then crossed the tracks of the electric railroad in the foreground of the view. Mud and debris completely ruined the agricultural land, destroyed one farmhouse, and seriously damaged the brick schoolhouse standing in the center of the mudflow fan.

Similar flows have poured out from many other canyons in semi-arid parts of the country. Lives have been lost and the property damage has been heavy. Sloping fans of jumbled mud, sand, and boulders at the mouths of canyons indicate to the geologist that mudflows have issued there at some time in the past. The miscellaneous character and arrangement of material which differentiate mudflow debris from stream deposits is well shown along roads which have been cut through mudflow fans.

The view below shows the surface of the fan and some of the debris left by the Parrish Canyon mudflow. The canyon mouth is in the background. The thickness of the deposit, probably 5 to 10 feet, makes it impracticable to uncover the fertile soil beneath. Larger blocks of rock are found on other parts of the fan.

THE MOST UNIVERSAL FORM of mass movement is the gradual downhill creep of the soil slowly moving toward the streams. This goes on so slowly that we cannot see it in action and therefore may fail to recognize its importance. Farmers who have found it necessary to realine their fences, or set new posts on hillside fields every few years, will realize that some gradual movement tilts the posts downhill. Monuments in many old cemeteries have a similar tilt, and broken retaining walls also show the power of soil creep.

In some parts of the country the entire topsoil and subsoil, or A and B horizons, have crept downhill over the parent material. Many road or railroad cuts and gully walls in the Piedmont and mountain areas of South Carolina and North Carolina, for example, show a distinct line between the B horizon and the parent material. In some cases there is a marked color change as in the wall of this gully in Spartanburg County, S. C., where a deep red clayey B horizon overlies light-gray rotten rock.

THE BASE OF EFFECTIVE SOIL CREEP is often marked by an accumulation of somewhat angular fragments of white quartz or other resistant rock material. A well-defined *stone line* of this sort crosses the center of the picture above, which shows the wall of a railroad cut in South Carolina east of Spartanburg. Beneath the stone line the original rock structure is preserved and is seen dimly in this view as a layer of hard rock dipping downward toward the right. Above the stone line rock structures are absent, a mature soil profile is developed, and the material sometimes shows a faint banding parallel to the slope of the land.

Where the rock is uniform in character or there are no resistant beds to furnish suitable material the stone line may be absent. The view on the opposite page shows a sharp division at the base of the subsoil but no clear stone line. Below the division the banded gray bedrock is seen dipping diagonally to the left. This rock is badly weathered but preserves its essential structure. Above the division line is a mature soil about 5 feet thick which in the field shows a definite downhill banding or lamination.

MARKED DIFFERENCES in soil, slope, land use, and erosion conditions are sometimes found on different sides of the same hill. In many places this is due to the structure of the underlying bedrock. Where the rock formations are composed of beds or layers, as in sandstones, limestones, and shales, the slope of one side of the hill may be determined by the angle to which the rock layers have been tilted. The opposite side of the hill then may slope according to the jointing or fracturing of the rock across these layers. In areas where beds of rock lie horizontally or where the rock is not divided into layers but is a solid uniform mass, such as granite, other factors determine the slopes.

In some areas the soil, slope, use, and erosion features of the land are markedly affected by the direction in which a hillside faces. The panoramic view at the top of the page shows the south slope of a hill in Barren County, Ky. Only a thin layer of poor soil overlies the ledges of bedrock on this hillside. This slope is entirely unsuitable for farming and is now occupied by scattered trees.

A distinct contrast is seen across the valley at the left on a cleared north-facing slope which shows almost no rock exposures and is quite suitable for pasture.

THE STEEPNESS OF A HILLSIDE is determined in part by the rate of washing of soil from its surface, by the rate of mass movement of soil down the slope, and by the vegetative cover and land use. The picture below shows an area in Barren County, Ky., during the melting of a 4- or 5-inch snowfall. The slope in the left foreground faces north and is still covered with snow. That across the valley faces south and has lost almost all its snow by melting.

This difference in the duration of snow cover on north-facing and south-facing slopes is due largely to the angle at which the sun's rays strike the hillside. A north-facing slope may be in the shade much of the day, and even if the sun does reach it the low angle at which the sunlight strikes the surface means that relatively little heat is received. South-facing slopes, on the other hand, are exposed to the sun a much greater part of the day. The rays strike at a high angle and a relatively large amount of heat is received causing more rapid melting.

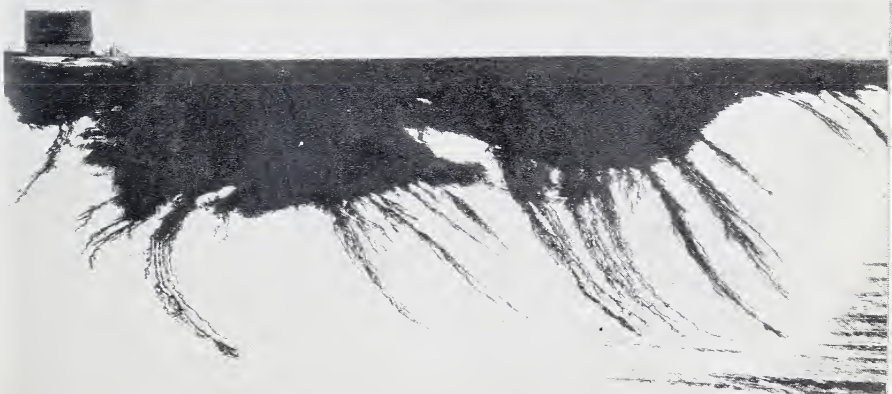
Soil under a solid blanket of snow does not wash away, and slopes covered with snow for a whole season are little affected by downhill creep of the soil. North-facing slopes are thus protected against erosion for a much greater part of the year than are south-facing slopes. Temperature fluctuations or changes from freezing to thawing are less frequent on the north side of hills and soil creep is therefore less active.

IN THIS VIEW TOWARD THE EAST in Walla Walla County, Wash., note the striking differences between the pine-covered north-facing slopes and the poorly vegetated slopes facing south. In subhumid and semiarid lands aspect is of great importance and north-facing hillsides have a double advantage. They receive less sun and therefore do not suffer as greatly from the excessive heat in summer when vegetation on south-facing slopes becomes parched and dry. More moisture is available to plants on the northerly slopes because snow which falls there is not melted off so rapidly and the water has a better chance to soak into the soil.

Direction of exposure in relation to prevailing winds also helps determine differences in vegetation and erosion caused by distribution of snowbanks. Snow tends to blow across the crest of a hill or ridge and accumulate in drifts on the lee side as shown in the picture below in Whitman County, Wash. Wind direction varies, but drifts are somewhat more common on the eastern and southeastern sides of hills.

MELTING OF SNOWBANKS sometimes causes serious rilling, gullying, and slippage of the soil. The picture above from Latah County, Idaho, shows a steep hillside seeded to winter wheat. Melting of the snowbank reveals a series of cavities where the snow has lain. Alternate freezing and thawing around the snowbanks tends to loosen the soil, and water from the melting snow carries it away. The cavities enlarge with each successive snowfall and soon endanger the whole hillside. The zone where the snowbank accumulates might better be left in permanent vegetation.

Erosion of soil during the disappearance of winter snows is sometimes strikingly shown where earth is deposited on snow fields. Melting of snow from the crest of this ridge in Whitman County, Wash., exposed the soil. Sheet wash and rilling have carried it downhill and out onto the remaining snow.



Erosion by Wind

WIND EROSION is of importance only in areas where there is insufficient vegetation to cover and bind the soil. This is the natural condition in arid lands and along the sandy shores of lakes, oceans, and some rivers. Sand dunes are common land forms in such places and storms of blowing sand have long been a danger to caravans and inhabitants of desert regions. Lack of vegetative cover on sand dunes allows them to shift their position with the winds. Migrating dunes have buried forests, houses, and even whole villages.

In recent years wind erosion and dust storms have increased in severity in the central-western part of the United States. Overgrazing has removed the vegetal cover from some of our semiarid range lands. Plowing up of the natural sod in parts of the Great Plains has exposed thousands of square miles of land which in years of adequate rainfall produces an excellent wheat crop but during dry periods is subject to serious wind erosion. Former grassland has been made to look much like a desert. Within this "dust bowl" the blowing material is not only sand but also valuable topsoil. It builds up into dunes, drifts along fences and around clumps of vegetation and buildings, and much of it is carried for hundreds of miles and deposited in the Eastern States or even in the ocean.

Wind scour or *deflation* in the rough arid lands of the Southwest carves weird-shaped pillars and cliffs. Where the sod has been broken in the plains country, wind strips off the topsoil leaving in some places only heavy unproductive subsoils. Irregular wind scour leaves residual mounds of the old soil held together at the top by bunches of grass, yucca, or other vegetation.

Protection against wind erosion and destruction by shifting dunes is best accomplished by the maintenance of a good vegetal cover on the soil. Wind erosion like sheet erosion acts over a broad area and cannot operate where there is tight sod or natural forest cover. Once the sand or soil accumulates into shifting dunes, means must be used to check the movement so that vegetation can gain a foothold. Selected grasses and trees can then be planted to provide permanent anchorage for the loose material.

SAND HILLS, OR SAND DUNES, are common features of the landscape on the shore of the ocean and along many lakes and rivers. Dunes which are bare of vegetation are "active" and free to move with the shifting winds. Sand is blown up one side, spills over the crest, and rolls down the other side. In this way a dune may migrate many feet in a single severe windstorm.

Large dunes, such as those along the eastern shore of Lake Michigan, one of which is shown above, are very destructive when they invade areas of valuable land, buildings, crops, or forests. This dune is moving toward the trees at the left. If it continues to migrate, the sand may completely cover the forest. Sand dunes in the past have buried forests, houses, churches, and whole villages, some of which have been uncovered many years later when a shift in the wind during a few storms has caused the sand to blow in another direction.

VARIOUS METHODS ARE USED to prevent the spread of shifting sands. Planting suitable grasses or other drought-resisting vegetation on dunes is often successful. Lines of stakes and other obstructions are sometimes used to cause deposition of the sand in drifts, thus preventing it from blowing onto valuable property. With the portable sand fence shown above on coastal dunes in Clatsop County, Oreg., the boards may be raised as the sand accumulates.

The lower picture shows the use of brush barriers to control the movement of sand dunes along the lake shore in Muskegon County, Mich. In the background is an old stabilized area on which vegetation is well established. If a break is made in the sod or forest cover on a sand hill or dune the wind is given a chance to take hold. It can undermine the remaining vegetation and quickly develop a large "blow-out" similar to the area shown here.

IN THE AREA SHOWN ABOVE, sand has drifted in front of a dwelling on the Oregon coast near Gearhart, in Clatsop County. Wind currents around the house tend to prevent sand actually piling against the building. Grass now partly covers the dune and retards its movement.

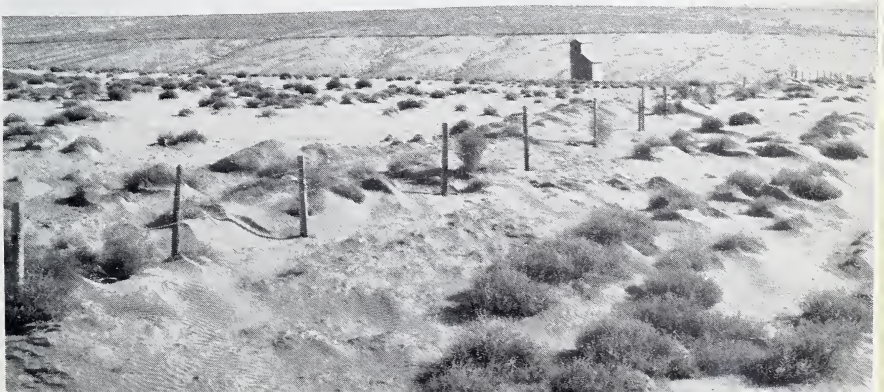
Many earlier pages have shown how overgrazing and devegetation increase erosion. Sand and silt thus produced wash into the rivers, and increase their load. In arid and semiarid regions there is seldom enough water to handle the added burden. Sand flats are formed along the river and the bare sand is readily moved by the winds. The sand dunes in the picture below lie on a broad flat along the north side of the Rio Salado in New Mexico. Before 1890 there was no extensive sand plain there. Now, owing to overgrazing, the sand piles high and blowing such as that in the background occurs frequently.

DUNES ARE NOT LIMITED TO SANDY SHORES and river flood plains but may form wherever there is loose dry sand or earth. In arid regions the whole surface is exposed to the winds and sand dunes are a prominent feature of the landscape. During periods of low precipitation the soil of semiarid or even subhumid parts of the country may be denuded of vegetation and dunes may develop.

These dunes in Dallam County, Tex., were active when the two pictures on this page were taken but experiments were under way testing methods of control. Listing on both sides of the dune and raising a crop of weeds, as shown here, provide a trap for the drifting sand or soil material, so that it is held in place and the dune has no opportunity to rebuild. The tops are not planted because on agricultural land the aim is to lower the dunes by flattening them out. The long unbroken dune in the lower picture gives some idea of the tremendous amount of material to be anchored.

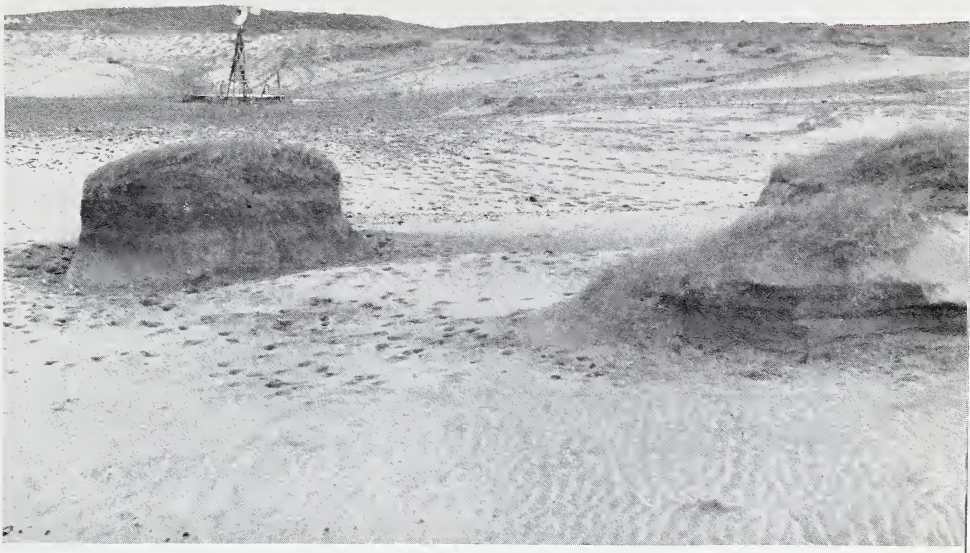
DRIFTING TOPSOIL, its surface rippled by the wind, has accumulated around the buildings and in the yard of this farm in Beadle County, S. Dak. Plants are covered by the blowing sand and soil, roads are obstructed, farm machinery buried, and fields piled with irregular hummocks or dunes. Road-grading machinery can be used for flattening out small accumulations on cultivated land.

The grain elevator in the picture below looks strangely out of place. This area in Adams County, Wash., shows something of the eroding effect of the wind. Blowing of the sandy soil has made the area appear much more arid than the elevator would indicate. The fields were plowed the previous year but were eroded to plow depth. Thistles came into the field while fallow and have served to hold quantities of sand in their lee, forming miniature dunes.



WHEN THERE IS NO COVERING VEGETATION and little moisture in the ground, the bare soil is at the mercy of the winds. Unprotected topsoil blows more easily than sand and can be carried greater distances. It fills the air, clouding the sun for days and giving a weird character to the light. In heavy blows, or "dusters", the fine soil gets into everything. Tightly closed houses are not adequate protection. The blowing soil is choking and blinding to animal and human alike.

Parts of the Great Plains have suffered especially heavily in a few recent drought years. In the areas from which the material is blown there may be nothing left but hard subsoil. This field in western Oklahoma was stripped down to the depth of cultivation as is shown by the intersecting pattern of lister marks from several years' tillage. The subsoil is tough and reveals a cracked structure similar to that formed by the drying out of mud flats.



CATTLE TRAILS TO AND FROM THE WATERING PLACE on this Nebraska ranch in the sand hills of Holt County, explain the lack of vegetation and topsoil in this view. Congregation of livestock causes excessive grazing and trampling of the vegetation. In years of normal precipitation grass protects the soil. In periods of drought the resistance of the grass is lowered and the trampling and grazing of animals collecting around the available water cause much of the grass to die. The bare soil is then exposed to the action of the wind. Once started, erosion goes faster as vegetation is cut away or buried by the shifting sands. The grass-covered mounds in this picture are remnants of the original surface and show the thickness of topsoil and subsoil which have been eroded.

Wind erosion lowers the value of the lands from which the soil is removed and, if the blowing material is sandy, its accumulation on farm lands elsewhere is usually detrimental. Neither the place of origin or of deposition benefits by wind erosion.

Erosion—Past, Present, and Future

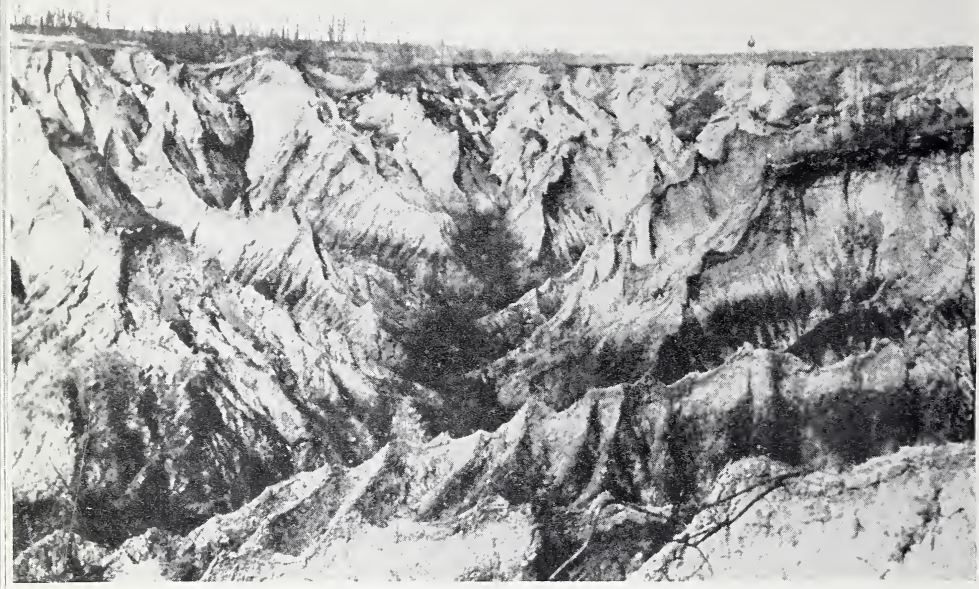
LOOKING INTO THE PAST we see the continuous working of geologic erosion. It has worn away and sculptured the surface of the earth since time immemorial and is an essential process of nature which has formed the landscape as we know it today. Natural erosion is a sign of a normal condition of the landscape. The process acts steadily but so slowly that generations are required for it to make any marked alterations in the major features of the earth's surface. Geologists have long studied erosion and have gained a rather full understanding of the processes by which it operates.

The great canyon shown on the opposite page is so spectacular and so beautiful that it was set aside for the public as Grand Canyon National Park. Early in its history it was little different from hundreds of other small valleys in the same region. Age-long erosion by the Colorado River has carved this tremendous gorge by carrying out each day and each year a little more rock and soil from this area which was once a continuous plateau, level from the camera to the horizon.

Yet the Grand Canyon is only in its infancy. The valley is deep and the sides slope steeply. Rock and soil are constantly falling and washing from the walls down into the canyon and being carried downstream. The river is always heavily loaded with sediment.

Geologists say the valley is only in its infancy because as these same processes of erosion are continued on into the future the canyon will steadily become broader. Tributaries will cut farther back into the level upland. The valley walls will become less steep and the erosive processes will gradually become slower. In distant ages to come the canyon will widen to twice, 5 times, or 10 or more times its present width. Instead of a deep narrow trench across a level plateau there will be a broad open valley and the distance from the river to the rim of the upland will be farther than the eye can see.

THE GRAND CANYON of the Colorado River, an awe-inspiring example of the work of natural erosion on the landscape.



AT THE PRESENT STAGE of agricultural development in the United States we are greatly concerned by the spread of an unnatural form of erosion. Ever since cultivation was started in this country, soil erosion has steadily sapped the vitality of the lands. The same has been true of other new countries where land was plentiful and little attention was paid to its conservation. Areas particularly susceptible to erosion were the first to be seriously affected. Many are now practically incurable. Other areas are severely afflicted but can be saved and started on a slow recovery if proper care and treatment are given. Prevention of soil erosion and prompt checking of it in incipient stages is worth more than any amount of curative work because hundreds of years are needed for nature to replace even a single inch of eroded topsoil.

The picture above shows an advanced stage of gully erosion in a flat area in Illinois. Since the picture was taken the jagged spurs of this large gully were graded to gentle slopes and planted with black locust. Within a single year the trees gained a foothold and now are rapidly binding the gully sides to insure against further expansion of the gully area.

THE CANYON OF THE YELLOWSTONE RIVER in Yellowstone National Park is vastly deeper and older than the gully on the opposite page. Large erosion features, however, grow from smaller ones, and this natural canyon was once no deeper than the Illinois gully.

Natural or geologic erosion is an essential process and will continue in the future regardless of anything man may do. Soil erosion is an abnormal and undesirable process started by man's activities and subject to his control. Whether this soil wastage is to be allowed to continue rests with the landowners, the producers and consumers of foodstuffs, and with the agronomists, geologists, foresters, engineers, and others who may be called in to help prescribe a cure and carry on the treatment. Unchecked erosion can make an entire district or State utterly worthless and drive out the human population. If we are to live permanently in these States we must adopt the attitude of farmers in older countries, that a man's land is his heritage to be cared for and passed on to his sons and grandsons. Lands must be built up, not depleted—the soil conserved, not washed away. To accomplish this we must work hand in hand with nature, and use strategy based on knowledge of the natural processes rather than waste our efforts in needless force.

ACKNOWLEDGMENTS

Sources of the following photographs are acknowledged: Hills along the Kentucky River, page 6, hoodoos in Colorado, page 27, aerial view of Parrish Canyon Mudflow, page 64, United States Forest Service; rolling Wisconsin farm land, page 6, Big Badlands, page 10, sand hills along Lake Michigan, page 73, Canyon of Yellowstone River, page 83, United States Geological Survey; brush barriers to hold blowing sand, page 74, United States Extension Service; Grand Canyon, page 81, United States Department of Interior. In the selection of illustrations and in the preparation of the manuscript the author has been assisted greatly by Lois Kremer Sharpe.